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Observation of Top Quarks in the Dilepton Decay Channel $t\bar{t} \rightarrow e\ (\mu)\upsilon_{e(\mu)}\tau\upsilon_{\tau}\ b\bar{b}$ Using Hadronic Tau Decays at CDF

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OBSERVATION OF TOP QUARKS IN THE DILEPTON DECAY CHANNEL $t\bar{t} \rightarrow e(\mu)\nu_{e(\mu)}\ \tau\nu_\tau\ b\bar{b}$ USING HADRONIC TAU DECAYS AT CDF

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We present a search for dilepton events from top decays with one electron or muon and a hadronically decaying τ lepton. The total acceptance×efficiency is $(0.119 \pm 0.014(stat))\%$ for $m_{top} = 175\ GeV$. In 110 pb^{-1} of data we expect $1.1 \pm 0.3(stat)$ signal events and a total background of $1.96 \pm 0.35(stat)$ events while observing 4 candidate events (2 $e\tau$ and 2 $\mu\tau$). Three events are b-tagged. If a tag is required, the probability for the estimated background (0.225 ± 0.011 events) to fluctuate to ≥ 3 events is 0.13% ($3.0\ \sigma$). A first measurement of the $t\bar{t}$ production cross section based on these events yields $\sigma_{t\bar{t}} = 15.6^{+18.6}_{-13.2}(stat)\ pb$.

1 Introduction

1.1 Decay Channel

We describe a search for Top quarks in the 'tau dilepton' channel using the CDF detector [1] at the Fermilab Tevatron. Specifically, we have searched for the $t\bar{t}$ decay mode with one electron or muon and one *hadronically* decaying tau lepton plus b-jets:

$$t\bar{t} \rightarrow W^+W^-b\bar{b} \rightarrow e(\mu) + \nu_{e(\mu)} + \tau + \nu_\tau + 2\ b\ jets.$$
$$\hookrightarrow hadrons + \nu_\tau$$

This decay mode of the top quark is predicted by the Standard Model and the first and obvious motivation for this search is to test that prediction. We note that this decay channel is especially interesting as the top decay into a b quark, a τ lepton and a τ neutrino involves exclusively members of the third lepton and quark families and one should always be on the lookout for unexpected behaviour. For instance, the existence of a charged Higgs boson [2] $H^\pm$ with a mass below the top mass could give rise to anomalous τ lepton production through the decay chain $t \rightarrow H^\pm b \rightarrow \tau\nu_\tau b$.

1.2 Branching Ratios in Top decays

In the Standard Model the top branching ratio BR($t \rightarrow Wb$) is predicted to be essentially 100% and therefore the final states in the decay of a $t\bar{t}$ pair are predicted to be determined by the BR's of the W's. To good approximation

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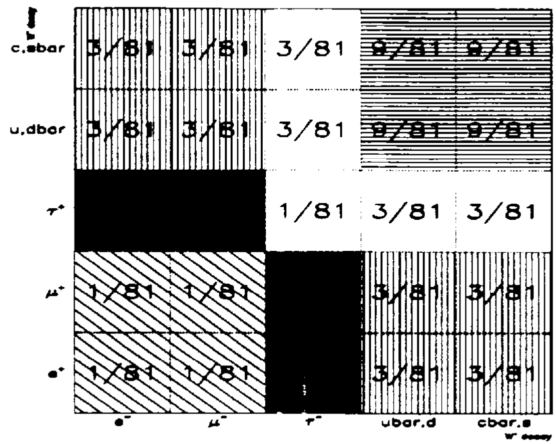

Figure 1: Matrix of $t\bar{t}$ decay channels in the Standard Model. We distiguish 5 different modes: 'Standard dileptons' (diagonal hatch), 'Lepton + jets' (vertical hatch), 'All-Hadronic' (horizontal hatch), 'Tau dileptons' (dense hatch), and 'Tau + jets' (no hatch).

Table 1: Signatures of $t\bar{t}$ decay channels and predicted Branching Ratios.

Channel	Signature	BR
'Standard dilepton'	$ee, \mu\mu, e\mu$ + 2 b jets	4/81
'Lepton + jets'	$e + jets, \mu + jets$ + 2 b jets	24/81
'All-Hadronic'	$jets, jets$ + 2 b jets	36/81
'Tau dilepton'	$e\tau, \mu\tau$ **+ 2 b *jets***	**4/81**
'Tau + jets'	$\tau + jets$ + 2 b jets	12/81

$BR(W \to l\nu_l) = 1/9$ for each leptonic channel and, due to the color factor, $BR(W \to q\bar{q'}) = 3/9$ for the available hadronic channels ($u\bar{d}$, $c\bar{s}$) [3]. In Figure 1 we show a matrix of all predicted Standard Model decay channels of the $t\bar{t}$ system and their branching ratios. We distinguish 5 decay modes: 'Standard dileptons', 'Lepton + jets', 'All-Hadronic', 'Tau dileptons', and 'Tau + jets' as indicated by the hatchings. In Table 1 we list the corresponding signatures and predicted branching ratios.

Note that the predicted BR for $e\tau$ and $\mu\tau$ events is 4/81, i.e. the same as for ee, $\mu\mu$, $e\mu$ combined and in principle the number of dilepton events could be doubled by including τ's. However, the BR for hadronic τ decays is about 64% and each τ decay involves an undetectable ν_τ which decreases the kinematic acceptance for the detectable τ decay products. Also, τ identification is less efficient than e or μ identification. This means that the total acceptance for tau dileptons is considerably smaller than for the standard dileptons.

1.3 *A brief history of observed Top decay modes*

The first direct evidence [4] for the top quark was presented by the CDF Collaboration in 1994 based on the Standard dilepton and the Lepton+jets channels using 19.3 pb^{-1} of data. Using larger data sets [a] the top quark was finally 'discovered' in 1995 by the CDF [5] and D0 [6] collaborations in these two decay channels. Also, during 1995 both collaborations presented first evidence for the All-Hadronic top decay mode [7,8], which leaves the two tau channels open. Here we present first results for the tau dilepton channel from CDF.

2 Event selection

2.1 *Primary lepton*

The selections of the primary e or μ are identical to those used for the top discovery in the standard dilepton channel [4]. In summary, we require a high-p_T ($E_T > 20$ GeV for e, $P_T > 20$ GeV/c for μ), central ($|\eta| < 1.0$) [9], isolated e or μ that passes tight identification cuts based on quantities measured with the calorimeter and tracking system.

2.2 *Tau selection*

Geometrical and kinematical acceptance

The PDG [3] lists a total branching ratio for τ decays into one charged hadron ("one-prongs") of (49.83±0.35)% and (14.38±0.24%) for decays into three charged hadrons ("three-prongs"), for a total of 64.21%. The vast majority of the charged hadrons in the final state are pions. About 73% of all one-prong and 41% of all three-prong decays are associated with at least one π^0. We identify π^0's by searching for the photons from the decay $\pi^0 \rightarrow \gamma\gamma$ in the strip chambers [1] located at approximately shower-maximum in the Central Electromagnetic Calorimeter (CEM). We define the p_T of the τ as the scalar sum of the p_T of the tracks in a 10^o cone around the center of the corresponding calorimeter cluster plus the E_T of any identified π^0's as measured in the CEM: $p_T^\tau = p_T^{trk+\pi^0} := p_T^{trk} + E_T^{EM}$. By incorporating π^0's we are able to increase the acceptance for hadronic τ decays by about 22%.

We determine the geometrical and kinematical acceptance $A_{geom \cdot P_T}$ for tau dileptons with a Monte Carlo simulation of $t\bar{t}$ production [10] by matching generated leptons to corresponding reconstructed leptons. We apply the following kinematical and geometrical requirements: $|\eta| < 1.0$ and $E_T(P_T) >$

[a] 67 pb^{-1} for CDF

Table 2: τ ID variables and cuts

Track multiplicity in 10^o cone:
use 1-prongs and 3-prongs only
E/p cut:
$0.25 < \frac{E_T}{p_T^{trk+\pi^0}} < 2.0$ (1-prongs)
$0.25 < \frac{E_T}{p_T^{trk+\pi^0}} < 1.2$ (3-prongs)
Sliding cut on RMS cluster width σ_{cl}:
$\sigma_{cl} < 0.11 - 0.025 \times E_T/100$ (1-prongs)
$\sigma_{cl} < 0.13 - 0.034 \times E_T/100$ (3-prongs)
Mass cut:
$m_{trk+\pi^0} < 1.8\ GeV$
of π^0's:
$\#\pi^0 < 3$
Track Isolation:
$I_{trk} < 1\ \frac{GeV}{c}$
Electron removal:
Reject 1-prongs with $E/p < 4$, EMFrac > 0.9 or clusters with EMFrac > 0.95 as electrons
Muon removal:
Reject clusters with $E_T < 8\ GeV$, $0.05 < E_{EM} < 2$ GeV, $0.5 < E_{Had} < 5$ GeV or with a muon stub with $\lvert\phi_\tau - \phi_{stub}\rvert < 15^o$ as muons

20 $GeV(GeV/c)$ for the primary e (μ) and $p_T^{trk+\pi^0} > 15\ GeV/c$, $|\eta| < 1.2$ for the hadronic tau. Due to isolation requirements (see below) we are only sensitive to τ's from W decays and primary leptons that are either due to W or leptonic τ decays. For these we find $A_{geom \cdot P_T} = (0.60 \pm 0.02(stat))\%$. Note that all branching ratios are included in this acceptance.

Tau identification

In Table 2 we list the various ID variables and cuts we use for identifying hadronically decaying τ's. We find that the ID variables for τ's are well modeled by the simulation and we therefore use simulated τ decays to set cuts and to calculate their efficiency. As an example we compare in Figure 2 two ID variable distributions for $W \rightarrow \tau\nu$ Monte Carlo plus estimated background

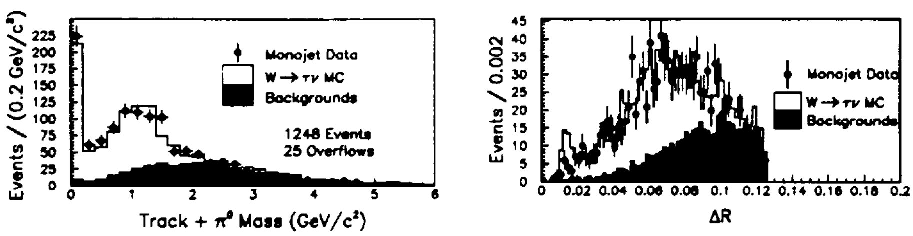

Figure 2: Left: Invariant mass of tau candidates in a monojet sample. Right: Calorimeter RMS width σ_{cl} of τ candidates in a monojet sample. The hard cut at approximately 0.123 is an effect of the Level 2 τ trigger. The points are the monojet data, the shaded histograms are the background contributions estimated from a generic jet sample and the open histograms are the Monte Carlo τ shapes plus the background shape (CDF preliminary).

from a generic jet sample with data from a 'monojet' data sample which is enriched with jets from hadronic τ decays from $W \rightarrow \tau\nu$ decays.

The cuts were chosen to be *simple* and *efficient* for τ's. At the same time they are intended to be effective in reducing the misidentification of generic jets as τ's. In Figure 3 we show distributions of the ID variables for simulated τ's together with distributions for generic dijets[11] to illustrate how we can separate hadronically decaying τ's from generic jet background. In the following we briefly discuss each the of the ID cuts:

1. Track multiplicity: Since most hadronic τ decays are into one-prongs and three-prongs we require that a reconstructed τ have a track multiplicity of either one or three in a 10^o cone around the cluster center. The ratio of signal to background for two-prongs is low and we do not use them.

2. E/p: Here we incorporate π^0's by defining E/p as $E_T/p_T^{trk+\pi^0}$. Because one-prongs have a larger high tail than three-prongs we make different cuts on the high side for one-prongs (2.0) and three-prongs (1.2) to get similar efficiencies. This cut is mostly useful for rejecting fake three-prongs and fake one-prongs with large E/p.

3. RMS cluster width σ_{cl}: The cluster width is defined as the second moment of the E_T distribution among the towers in the cluster $\sigma_{cl} := \sqrt{\sigma_\phi^2 + \sigma_\eta^2}$. Figure 3 shows how we can capitalize on the fact that τ clusters are narrower than clusters from generic jets. The showers become more collimated with increasing E_T and the cluster width decreases. We take this effect into account by making a sliding cluster width cut. Since we find differing behavior for one-prongs and three-prongs we use different parameters for the two cases.

4. Mass: We reconstruct the invariant mass of a τ from the tracks in the 10^o cone and the π^0's associated with a cluster. For one-prongs without any identified π^0's we set the mass equal to the π mass (140 MeV). We find that a physically well motivated cut near the actual τ mass (1.777 GeV) has good efficiency for τ's and good rejection power against generic jets.

5. Number of π^0's : Tau decays basically do not involve more than 2 π^0's, so we require that we reconstruct less than 3 π^0's in a cluster. This cut is very efficient for τ's after all other cuts have been applied.

6. Tracking Isolation: I_{trk} is defined as ΣP_T of all tracks in a cone of 0.4 around the cluster center which are not in the 10^o cone that defines the track multplicity. We use a tight, absolute cut of $I_{trk} < 1\frac{GeV}{c}$.

7. Electron Removal: Electrons produce very narrow clusters with one track pointing at them and can therefore be mistaken as one-prong τ's. We rely on the high electromagnetic fraction in electron clusters to reject them.

8. Muon Removal: Muons are minmum ionizing particles and deposit little energy in the calorimeter tower that they hit. Clusters are rejected either if there is a stub in the muon chambers within 15^o of the cluster or if the energy deposition in the calorimeter is consistent with that of a minimum ionizing particle.

We list the efficiency of all cuts for hadronic τ decays as determined from the $t\bar{t}$ Monte Carlo simulation in Table 3. The total ID efficiency is $\epsilon^{\tau}_{ID} = (51.2 \pm 2.7(stat))\%$ and is found to be flat as a function of $p_T^{trk+\pi^0}$.

3 Topology cuts

In order to separate the top signal from the backgrounds we apply cuts on the event topology. For the b jets expected in top dilepton events we use the same jet cut as the standard dilepton analysis: ≥ 2 jets with $E_T^{uncorr.} >$ 10 GeV and $|\eta| < 2.0$. It has been shown that a cut on the H_T variable [12] can be quite effective in reducing background in the top analysis while retaining high efficiency for the top signal. Therefore, we apply an H_T cut using the following definition of H_T for tau dileptons: $H_T := E_T^{el}(p_T^{\mu}) + p_T^{trk+\pi^0} + \not{E}_T + \sum_{jets} E_T^{uncorr.} > 180$ GeV. We correct the missing transverse energy $\not{E}_T$ for muons and jets in the same way as the standard dilepton analysis treating the τ jet as a generic jet for the purpose of the $\not{E}_T$ correction. We apply a cut on the $\not{E}_T$ significance $\sigma_{\not{E}_T} := \frac{\not{E}_T}{\sqrt{\Sigma E_T}}(\frac{\not{E}_T}{\sqrt{\Sigma E_T + p_T^{\mu}}}) > 3$ $GeV^{1/2}$ for $e\tau$ ($\mu\tau$). ΣE_T is the scalar sum of the transverse energy measured in the calorimeter towers.

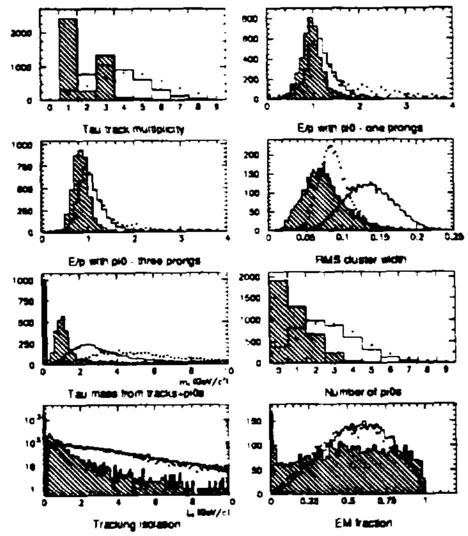

Figure 3: Comparison of τ ID variables for τ's in a $t\bar{t}$ MC (hatched) and for generic jets from a JET20(solid histogram) and a JET70(dots) sample[11] (CDF preliminary).

4 Total Acceptance $\times$ Efficiency

The total acceptance $\times$ efficiency A_{tot} for tau dilepton events is given by:

$$A_{tot} = A_{geom \cdot P_T} \times \epsilon^{e,\mu}_{Iso} \times \epsilon^{e,\mu}_{ID} \times \epsilon^{\tau}_{ID} \times \epsilon_{opp.sgn} \times \epsilon^{e,\mu}_{trig} \times \epsilon_{Zrem.} \times \epsilon_{jets} \times \epsilon_{H_T} \times \epsilon_{top}. \tag{1}$$

In Table 4 we collect all the acceptances and efficiencies for $e\tau$ and $\mu\tau$ events. Putting everything together find $A_{tot} = (0.119 \pm 0.014(stat))\%$.

With A_{tot} in hand we can calculate how many tau dilepton events from top we expect to find in 110 pb^{-1}. Using an experimental estimate of the top production cross section by CDF from other top decay modes ($\sigma_{t\bar{t}} = 8.5^{+2.1}_{-1.8}$) we find: $N^{\tau-dilepton}_{expected} = \sigma_{t\bar{t}}\ \mathcal{L}\ A_{tot} = 1.1 \pm 0.3(stat)$ events where we assume an 8% error on the total integrated luminosity.

5 Backgrounds

5.1 Fakes

Generic Jets can fake hadronic τ decays. Even though the τ ID cuts discussed above are tailored towards minimizing this background, there is always a (small) probability for a jet to fragment with low track multiplicity. With our ID cuts this is basically indistiguishable from a τ decay and hence constitutes

Table 3: Efficiency of τ ID cuts in MC top dilepton events for τ's from W's. In the column 'Cut in question only' we simply list the fraction of events passing the cut in question. Under 'All other cuts applied' we list the fraction of events passing the cut in question for events that pass all other ID cuts.

	Cut in question	All other cuts applied	Cumulative cuts
Track multiplicity 1 or 3	90.2%	96.1%	90.2%
E/p with π^0	97.3%	96.6%	87.7%
slid. RMS Cluster width cut	86.2%	91.0%	77.9%
$m_{trk+\pi^0} < 1.8\ GeV$	76.6%	86.3%	63.1%
Number of $\pi^0 < 3$	91.6%	98.5%	61.7%
$I_{trk} < 1\ GeV/c$	83.4%	91.5%	56.1%
Electron removal	95.1%	96.4%	54.2%
Muon removal	94.3%	94.5%	51.2%
TOTAL efficiency	(51.2±2.7)%		

an irreducible background. A $W+ \geq 3$ *jets* event where one jet is misidentified as a τ would then give us a fake tau dilepton event.

We calculate the fake rate by applying the τ selection to jets in samples of generic dijets. The total fake rate drops from 0.5% at $E_T^{jet} \approx 20\ GeV$ to about 0.1% at 50 GeV and stays flat at this level out to 100 GeV.

We calculate the expected number of background events by multiplying the fake rate as a function of E_T bin-by-bin with the E_T spectrum of all $\tau-$taggable jets ($|\eta| < 1.2$) in a $W+ \geq 3$ *jets* sample and then summing over all bins. In 110 pb^{-1} we find 180 events with 480 jets. The resulting sum is divided by 2 to take the opposite sign cut into account as we expect the fake rate for same-sign events and opposite-sign events to be the same.

5.2 *Physics backgrounds*

The main background from physics processes containing real τ's is $Z \rightarrow \tau^+\tau^- +$ *jets*. If one τ decays leptonically and the other τ hadronically this process can mimic the top signature. Smaller background contributions are expected from diboson production (WW, WZ). Also, $Z \rightarrow e^+e^- +$*jets* and $Z \rightarrow \mu^+\mu^- +$*jets* processes contribute to the backgrounds as e's and μ's can fake τ signals. From MC simulations [13] we expect a total background including fakes of 1.96±0.35 events. Table 5 lists the contributions from the various background sources.

We check if our Monte Carlo based background calculation is reasonable by relaxing topological and kinematical cuts, recalculating the background and

Table 4: Collection of efficiencies needed for calculating A_{tot} . Only stat. errors are given.

	$e\tau$	$\mu\tau$
$A_{geom\cdot P_T}$	0.27±0.02%	0.33±0.02%
$\epsilon^{e,\mu}_{Iso}$	0.880±0.020	0.904±0.017
$\epsilon^{e,\mu}_{ID}$	0.814±0.008	0.933±0.006
ϵ^{τ}_{ID}	0.512±0.027	
$\epsilon_{opp.sign}$	0.995±0.005	
$\epsilon^{e,\mu}_{trigger}$	1.0	0.871±0.028
$\epsilon_{Zremoval}$	0.987±0.012	1.0
ϵ_{jets}	0.882±0.022	
ϵ_{H_T}	0.927±0.019	
$\epsilon_{topology}$	0.661±0.035	

comparing to data. In a first step we drop the H_T cut and in a second step we additionally relax the $\not{E}_T$ requirement by requiring $\not{E}_T > 15\ GeV$, but not cutting on $\sigma_{\not{E}_T}$ at all. Both are done separately for events with one jet and for events with ≥ 2 jets. The results of the background calculations and the expected number of events from top are listed in Table 5. We find that the background calculation agrees well with the observed number of events in the data in all cases. This gives us confidence that our background estimate for the signal region is also reasonable.

6 Observation in the data

In Figure 4 (top) we plot $\sigma_{\not{E}_T}$ versus the corrected $\not{E}_T$ for events with a primary lepton and a τ candidate that passes all ID cuts, the opposite sign cut and Z removal cuts. We then plot the events that survive if we consecutively apply the other topology cuts, i.e. the ≥ 2 jet cut (center) and H_T cut (bottom). In the plots on the right hand side the $\sigma_{\not{E}_T}$ cut is applied. After all cuts we are left with 4 final candidate events for tau dileptons: 2 $e\tau$ and 2 $\mu\tau$ events. Note that 3 events are distinctly separated from the other events in the top plot. In Table 6 we list the characteristics of our 4 candidate events.

7 B-tagging

Checking the b-tagging information from the standard soft-lepton and secondary-vertex taggers[4,5] we find that 3 of the 4 events are b–tagged (see Table 6). We calculate the expected background for the 2 largest backgrounds: For τ fakes we multiply the τ fake rate with the jet E_T spectrum of tagged events in our

Table 5: Comparison of background calculation and data for relaxed topological and kinematical cuts. Note that the column for ≥ 2 jets and after all cuts summarizes the background calculation in the signal region.

All cuts applied:

N_{jet} (10 GeV)	1	≥ 2
τ fakes	0.37±0.03	0.63±0.04
$Z \to \tau^+\tau^-$	0.36±0.16	0.92±0.29
$Z \to e^+e^-$	0.00±0.16	0.00±0.10
$Z \to \mu^+\mu^-$	0.00±0.07	0.18±0.13
WW	0.13±0.08	0.18±0.09
WZ	0.02±0.01	0.05±0.03
TOTAL	0.88±0.25	**1.96±0.35**
expected from top	0.11±0.03	1.1±0.3
DATA	0	4

Drop the H_T cut:

N_{jet} (10 GeV)	1	≥ 2
τ fakes	3.56±0.24	1.36±0.09
$Z \to \tau^+\tau^-$	2.45±0.42	1.56±0.38
$Z \to e^+e^-$	0.00±0.16	0.09±0.09
$Z \to \mu^+\mu^-$	0.21±0.12	0.18±0.13
WW	0.49±0.15	0.18±0.09
WZ	0.03±0.02	0.06±0.03
TOTAL	6.74±0.54	3.43±0.43
expected from top	0.14±0.03	1.2±0.3
DATA	7	4

Drop the H_T and $\sigma_{\not E_T}$ cuts, but require $\not E_T > 15$ GeV:

N_{jet} (10 GeV)	1	≥ 2
τ fakes	8.3±0.6	3.5±0.2
$Z \to \tau^+\tau^-$	10.8±0.9	4.2±0.6
$Z \to e^+e^-$	0.8±0.4	0.3±0.2
$Z \to \mu^+\mu^-$	0.9±0.3	0.6±0.2
WW	0.8±0.2	0.3±0.1
WZ	0.1±0.1	0.1±0.1
TOTAL	21.7±1.2	9.0±0.7
expected from top	0.2±0.1	1.7±0.4
DATA	22	13

Table 6: Characteristics of the 4 tau dilepton candidate events. Note that the impact parameter d is just the value returned by the track fit, *not* a signed impact parameter with respect to a jet axis

Type	$e^-\tau^+$	$\mu^+\tau^-$	$e^-\tau^+$	$\mu^+\tau^-$
Primary lepton:				
E_T , p_T [GeV, GeV/c]	27.3	46.1	60.1	22.3
ϕ [deg]	255	241	66	181
η_{det}	0.07	0.0	0.20	0.141
Tau lepton:				
ϕ [deg]	356	70	275	81
η_{det}	-0.25	1.09	0.03	0.12
$p_T^{trk+\pi^0}$ [GeV/c]	81.9	33.9	30.0	45.5
p_T [GeV/c]	32.4	33.9	30.0	45.5
Track multiplicity	1-prong	1-prong	1-prong	1-prong
E/p (using $p_T^{trk+\pi^0}$)	1.03	1.88	0.67	1.53
RMS cluster width σ_{cl} [GeV]	0.069	0.067	0.077	0.086
$m_{trk+\pi^0}$ [GeV/c^2]	0.893	0.141	0.141	0.141
# of π^0's	1	0	0	0
impact par. d [microns]	1	-	147	93
impact par. signif. d/σ	0.04	-	9.4	6.8
I_{trk} [GeV/c]	0.0	0.0	0.0	0.44
e,μ-τ inv. mass [GeV/c^2]	73.7	86.4	82.8	48.8
Jets:				
# jets ($E_T > 10, \lvert\eta_{det}\rvert < 2.0$)	3	2	2	3
$E_T^{j_1}$ (uncorr.) [GeV]	39.6	95.9	42.6	169.3
$E_T^{j_2}$ (uncorr.) [GeV]	20.8	47.7	15.7	35.4
$E_T^{j_3}$ (uncorr.) [GeV]	15.9	9.8	-	14.2
MET et al.:				
corr. $\not{E}_T$ [GeV]	78.3	128.4	54.0	57.4
ΣE_T [GeV]	271.6	254.8	197.0	328.1
$\sigma_{\not{E}_T}[\sqrt{GeV}]$	4.8	8.0	3.9	3.2
$\Delta\phi$ ($\not{E}_T, jl$) [deg]	65.6	6.1	1.5	0.1
H_T [GeV]	274.3	391.5	192.5	368.4
b-tagging	Soft e(j2)	Soft μ(j1) Soft e(j2)	second. vert.(j1)	–

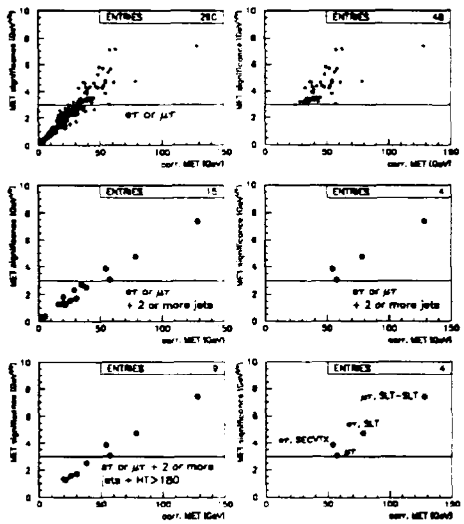

Figure 4: $\sigma_{\not E_T}$ vs $\not E_T$ for CDF data ($110\,pb^{-1}$). Top: after identifying a primary e or μ and a τ lepton. Center: after requiring 2 jets. Bottom: after requiring 2 jets and $H_T > 180\ GeV$. In the plots on the right the $\sigma_{\not E_T}$ cut is applied (CDF preliminary).

W+$\geq$3 jets sample after applying all other cuts. Based on 48 *tagged* events with 143 jets we find a background prediction of (0.21$\pm$0.01) events. The next largest background is expected to be due to $Z \rightarrow \tau^+\tau^- + b\bar{b},\ c\bar{c}$. We estimate this background to be (0.015$\pm$0.005) events. The probabilty for the total background of (0.225$\pm$0.011) events to fluctuate to $\geq$ 3 events is 0.13%. This value corresponds to a 3 σ excess on a Gaussian distribution.

8 Cross section

We calculate a $t\bar{t}$ production cross section from tau dilepton events: $\sigma_{t\bar{t}} = \frac{N^{observed} - N^{background}}{\mathcal{L}\ A_{tot}}$ where $N^{observed}$ is the number of observed candidate events (4), $N^{background}$ is our estimate for the background (1.96$\pm$0.35 events), $\mathcal{L}$ is the integrated Luminosity for Run 1A+1B (110$\pm$9 pb^{-1}) and A_{tot} is the total acceptance $\times$ efficiency (0.119$\pm$0.014%). Note that A_{tot} contains all branching ratios. To calculate the statistical error we use Poisson statistics for $N^{observed}$ and propagate all errors. Our final result is

$$\sigma_{t\bar{t}} = 15.6^{+18.6}_{-13.2}(stat)\ pb \qquad (2)$$

The statistical error obviously dominates the uncertainty. Studies of systematic errors are under way.

9 Summary and Conclusion

We have searched for top dilepton events with hadronically decaying τ leptons. For this purpose we have developed a method for identifying hadronic τ's with good efficiency and small fake background from jets. We expect about 1 signal event and 2 total background events in Run 1 (110 pb^{-1}) and observe 4 candidate events. The fact that 3 are b–tagged leads us to the conclusion that we are actually observing top quark decays into τ's. If a tag is required the probability for the background to fluctuate to ≥ 3 events is 0.13%, which corresponds to a 3.0 σ (Gaussian) excess. We have presented the first measurement of the top quark production cross section based on hadronically decaying τ leptons.

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9. In the CDF coordinate system, θ is the polar angle with respect to the proton beam direction. The pseudorapidity η is defined as -ln tan($\theta/2$). The transverse momentum of a particle is $P_T = Psin\theta$. If the magnitude of this vector is obtained using the calorimeter energy rather than the spectrometer momentum, it becomes the transverse energy E_T. The difference between the vector sum of all the transverse energies in an event and zero is the missing transverse energy ($\not{E}_T$).
10. We generate $t\bar{t}$ events for $m_{top} = 175\ GeV/c^2$ using the PYTHIA 5.6 event generator and a full CDF detector simulation. Effects due to tau polarization are taken into account by using the TAUOLA package.
11. Shown are 2 generic dijet samples obtained from jet triggers with thresholds $E_T^{jet} > 20\ GeV$ and 70 GeV, respectively.
12. F. Abe *et al.*, *Phys. Rev. Lett.* **75**, 3997 (1995).
13. We use the VECBOS generator for simulating $Z + jets$ processes and PYTHIA 5.6 for diboson production.